In [1]:

```
# ANOVA Monofactorial

# 1. Carga inicial de datos:

if(!require(psych)){install.packages("psych")}
if(!require(FSA)){install.packages("FSA")}
if(!require(Rmisc)){install.packages("Rmisc")}
if(!require(ggplot2)){install.packages("ggplot2")}
if(!require(car)){install.packages("car")}
if(!require(multcompView)){install.packages("multcompView")}
if(!require(multcompView)){install.packages("multcomp")}
if(!require(lsmeans)){install.packages("lsmeans")}
if(!require(rcompanion)){install.packages("rcompanion")}

Datos <- ("
Algoritmo      Ejecucion    Puntaje
'ERA'            '1'         45033
'ERA'            '2'         46623
'ERA'            '3'         43845
'ERA'            '4'         48849
'ERA'            '5'         45471
'ERA'            '6'         47132
'ERA'            '7'         46175
'ERA'            '8'         44015
'ERA'            '9'         46189
'ERA'            '10'        48499
'ERA'            '11'        42445
'ERA'            '12'        49155
'ERA'            '13'        48019
'ERA'            '14'        49068
'ERA'            '15'        42040
'ERA'            '16'        42538
'ERA'            '17'        44734
'ERA'            '18'        49899
'ERA'            '19'        47471
'ERA'            '20'        42966
'ERA'            '21'        42895
'ERA'            '22'        49284
'ERA'            '23'        45463
'ERA'            '24'        48812
'ERA'            '25'        43817
'ERA'            '26'        42326
'ERA'            '27'        43323
'ERA'            '28'        43482
'ERA'            '29'        44474
'ERA'            '30'        48576
'ERA'            '31'        42984
'ERA'            '32'        42914
'ERA'            '33'        48492
'ERA'            '34'        44776
'ERA'            '35'        48997
'ERA'            '36'        42966
'ERA'            '37'        42632
'ERA'            '38'        48334
'ERA'            '39'        45233
'ERA'            '40'        43456
'ERA'            '41'        46802
'ERA'            '42'        45332
'ERA'            '43'        43422
'ERA'            '44'        46946
'ERA'            '45'        42401
'ERA'            '46'        43473
'ERA'            '47'        45527
'ERA'            '48'        42785
'ERA'            '49'        47040
'ERA'            '50'        46662
'ERA'            '51'        49270
'ERA'            '52'        45591
'ERA'            '53'        46501
'ERA'            '54'        48277
'ERA'            '55'        47178
'ERA'            '56'        47658
'ERA'            '57'        49259
'ERA'            '58'        46043
'ERA'            '59'        46578
```

```
'ERA'           '60'        45165
'CFS'           '1'         42906
'CFS'           '2'         43517
'CFS'           '3'         42032
'CFS'           '4'         41393
'CFS'           '5'         42820
'CFS'           '6'         44951
'CFS'           '7'         41741
'CFS'           '8'         45950
'CFS'           '9'         42535
'CFS'           '10'        44958
'CFS'           '11'        44690
'CFS'           '12'        40945
'CFS'           '13'        44157
'CFS'           '14'        44550
'CFS'           '15'        42781
'CFS'           '16'        43145
'CFS'           '17'        43578
'CFS'           '18'        44312
'CFS'           '19'        45834
'CFS'           '20'        44558
'CFS'           '21'        42529
'CFS'           '22'        44373
'CFS'           '23'        46034
'CFS'           '24'        42572
'CFS'           '25'        41411
'CFS'           '26'        45356
'CFS'           '27'        44186
'CFS'           '28'        43339
'CFS'           '29'        45815
'CFS'           '30'        43666
'CFS'           '31'        45324
'CFS'           '32'        45427
'CFS'           '33'        41425
'CFS'           '34'        43171
'CFS'           '35'        40805
'CFS'           '36'        41931
'CFS'           '37'        40793
'CFS'           '38'        41542
'CFS'           '39'        45018
'CFS'           '40'        41054
'CFS'           '41'        44277
'CFS'           '42'        45672
'CFS'           '43'        46409
'CFS'           '44'        43394
'CFS'           '45'        43966
'CFS'           '46'        46300
'CFS'           '47'        46196
'CFS'           '48'        42279
'CFS'           '49'        45212
'CFS'           '50'        43758
'CFS'           '51'        43222
'CFS'           '52'        41552
'CFS'           '53'        41354
'CFS'           '54'        45633
'CFS'           '55'        44274
'CFS'           '56'        41765
'CFS'           '57'        45777
'CFS'           '58'        45205
'CFS'           '59'        42317
'CFS'           '60'        41959
'ULE'           '1'         45512
'ULE'           '2'         42095
'ULE'           '3'         41297
'ULE'           '4'         43138
'ULE'           '5'         40823
'ULE'           '6'         43642
'ULE'           '7'         40638
'ULE'           '8'         44984
'ULE'           '9'         43633
'ULE'           '10'        42653
'ULE'           '11'        41374
'ULE'           '12'        41558
'ULE'           '13'        41849
'ULE'           '14'        45989
'ULE'           '15'        42002
```

```
'ULE'           '16'        44388
'ULE'           '17'        41622
'ULE'           '18'        42974
'ULE'           '19'        44685
'ULE'           '20'        44343
'ULE'           '21'        43707
'ULE'           '22'        45049
'ULE'           '23'        42358
'ULE'           '24'        40590
'ULE'           '25'        45059
'ULE'           '26'        40714
'ULE'           '27'        42034
'ULE'           '28'        45881
'ULE'           '29'        40350
'ULE'           '30'        41908
'ULE'           '31'        41146
'ULE'           '32'        40614
'ULE'           '33'        40719
'ULE'           '34'        40340
'ULE'           '35'        42265
'ULE'           '36'        45164
'ULE'           '37'        44624
'ULE'           '38'        45495
'ULE'           '39'        44174
'ULE'           '40'        40461
'ULE'           '41'        44851
'ULE'           '42'        45542
'ULE'           '43'        42928
'ULE'           '44'        45616
'ULE'           '45'        45940
'ULE'           '46'        45587
'ULE'           '47'        45573
'ULE'           '48'        41625
'ULE'           '49'        40204
'ULE'           '50'        43319
'ULE'           '51'        41055
'ULE'           '52'        40471
'ULE'           '53'        43741
'ULE'           '54'        43889
'ULE'           '55'        40335
'ULE'           '56'        40163
'ULE'           '57'        45193
'ULE'           '58'        40631
'ULE'           '59'        40973
'ULE'           '60'        42638
'Monotonic'     '1'         32490
'Monotonic'     '2'         39163
'Monotonic'     '3'         32927
'Monotonic'     '4'         38382
'Monotonic'     '5'         33590
'Monotonic'     '6'         39663
'Monotonic'     '7'         32283
'Monotonic'     '8'         32621
'Monotonic'     '9'         37613
'Monotonic'     '10'        37005
'Monotonic'     '11'        35527
'Monotonic'     '12'        39317
'Monotonic'     '13'        32426
'Monotonic'     '14'        36812
'Monotonic'     '15'        32478
'Monotonic'     '16'        35713
'Monotonic'     '17'        37565
'Monotonic'     '18'        32738
'Monotonic'     '19'        38524
'Monotonic'     '20'        33706
'Monotonic'     '21'        39618
'Monotonic'     '22'        34218
'Monotonic'     '23'        35823
'Monotonic'     '24'        35597
'Monotonic'     '25'        39642
'Monotonic'     '26'        33650
'Monotonic'     '27'        33173
'Monotonic'     '28'        33812
'Monotonic'     '29'        38799
'Monotonic'     '30'        36139
'Monotonic'     '31'        32847
```

```
'Monotonic'      '32'        39100
'Monotonic'      '33'        35042
'Monotonic'      '34'        38256
'Monotonic'      '35'        39075
'Monotonic'      '36'        36629
'Monotonic'      '37'        35159
'Monotonic'      '38'        38597
'Monotonic'      '39'        34461
'Monotonic'      '40'        35573
'Monotonic'      '41'        38843
'Monotonic'      '42'        34925
'Monotonic'      '43'        33918
'Monotonic'      '44'        33043
'Monotonic'      '45'        36867
'Monotonic'      '46'        33323
'Monotonic'      '47'        38749
'Monotonic'      '48'        39796
'Monotonic'      '49'        37803
'Monotonic'      '50'        38739
'Monotonic'      '51'        36559
'Monotonic'      '52'        38500
'Monotonic'      '53'        35794
'Monotonic'      '54'        39715
'Monotonic'      '55'        38674
'Monotonic'      '56'        35441
'Monotonic'      '57'        34091
'Monotonic'      '58'        32393
'Monotonic'      '59'        32975
'Monotonic'      '60'        38212
")

# Lectura de los datos
Data <- read.table(textConnection(Datos), header=TRUE)
# Ordenar los datos segun los ingresamos
Data$Algoritmo <- factor(Data$Algoritmo, levels = unique(Data$Algoritmo))

# 2. Lectura de datos / Verificación de lectura

library(psych)
headTail(Data)
str(Data)
summary(Data)
rm(Datos)

# 3. Resumen organizado

Summarize(Puntaje ~ Algoritmo, data = Data, digits = 4)

# 4. Diagrama de cajas

M <- tapply(Data$Puntaje, INDEX = Data$Algoritmo, FUN = mean)
boxplot(Puntaje ~ Algoritmo, data = Data)
points(M, col = "red", pch = "+", cex = 2)

# 5. Información de promedios e intervalos de confianza

Sum <- groupwiseMean(Puntaje ~ Algoritmo, data = Data, conf = 0.95, digits = 3, traditional = FALSE, percent
Sum

# 6. Gráficos de promedios e intervalos de confianza

library(ggplot2)
ggplot(Sum,
       aes(x = Algoritmo, y = Mean)) +
       geom_errorbar(aes(ymin = Percentile.lower,
                         ymax = Percentile.upper),
                         width = 0.05, size = 0.5) +
                    geom_point(shape = 15,
                               size = 4) +
                    theme_bw() +
                    theme(axis.title = element_text(face = "bold")) +
                    ylab("Puntaje promedio, s")

#  Validacion de supuestos de ANOVA
#  Supuesto de normalidad y homocedasticidad
```

```r
# 7. Modelo Lineal

model <- lm(Puntaje ~ Algoritmo, data = Data)
summary(model)

# 8. Histograma de residuos

X <- residuals(model)
library(rcompanion)
dev.new()
#  Para evitar error "figure margins too large"
windows.options(width = 10, height = 8)
plotNormalHistogram(X)
#  Los residuos son normales

# 9. Dispersión de residuos

plot(fitted(model),residuals(model))
#  La dispersion es la misma

# 10. Gráficos del modelo lineal

plot(model)

# Se cumplen los supuestos

# 11. ANOVA

library(car)
Anova(model, type = "II")

# P-Value < alpha -> Se rechaza H0

# ------

# Ajuste de promedios | Mínimos cuadrados | Post-Hoc

# 1. Separación de promedios

library(multcompView)
library(lsmeans)
marginal <- lsmeans(model, ~ Algoritmo)
pairs(marginal, adjust="tukey")

# 2. Visión compacta

library(multcomp)
CLD <- cld(marginal, alpha=0.05, Letters = letters, adjust = "tukey")
CLD

# Ordenamos los niveles para imprimirlos
CLD$Algoritmo <- factor(CLD$Algoritmo, levels = c("ERA", "CFS", "ULE", "Monotonic"))
# Removemos espacios en blanco
CLD$.group <- gsub(" ", "", CLD$.group)

# Era estadisticamente distinto a CFS, ULE y Monotonic
# CFS y ULE estadisticamente equivalentes.
# Monotonic estadisticamente distinto a CFS, ULE y Monotonic

library(ggplot2)
ggplot(CLD,
       aes( x = Algoritmo,
            y = lsmean,
            label = .group)) +
       geom_point(shape = 15, size = 4) +
       geom_errorbar(aes(ymin = lower.CL,
                         ymax = upper.CL),
                         width = 0.2,
                         size = 0.7) +
       theme_bw() +
       theme(axis.title = element_text(face = "bold"),
             axis.text = element_text(face = "bold"),
             plot.caption = element_text(hjust = 0)) +

       ylab("Promedio del minimo cuadrado \n
             Tiempo de ejecucion") +
```

```
      geom_text(nudge_x = c(0,0,0),
                nudge_y = c(1100, 1100, 1100),
                color = "black")
```

```
Loading required package: psych

Loading required package: FSA

## FSA v0.9.4. See citation('FSA') if used in publication.
## Run fishR() for related website and fishR('IFAR') for related book.


Attaching package: 'FSA'


The following object is masked from 'package:psych':

    headtail


Loading required package: Rmisc

Loading required package: lattice

Loading required package: plyr


Attaching package: 'plyr'


The following object is masked from 'package:FSA':

    mapvalues


Loading required package: ggplot2


Attaching package: 'ggplot2'


The following objects are masked from 'package:psych':

    %+%, alpha


Loading required package: car

Loading required package: carData

Registered S3 methods overwritten by 'car':
  method       from
  hist.boot    FSA
  confint.boot FSA


Attaching package: 'car'


The following object is masked from 'package:FSA':

    bootCase


The following object is masked from 'package:psych':

    logit


Loading required package: multcompView

Loading required package: lsmeans

Loading required package: emmeans

The 'lsmeans' package is now basically a front end for 'emmeans'.
Users are encouraged to switch the rest of the way.
See help('transition') for more information, including how to
convert old 'lsmeans' objects and scripts to work with 'emmeans'.
```

```
Loading required package: rcompanion


Attaching package: 'rcompanion'


The following object is masked from 'package:psych':

    phi
```

A data.frame: 9 × 3

	Algoritmo	Ejecucion	Puntaje
	<fct>	<chr>	<chr>
1	ERA	1	45033
2	ERA	2	46623
3	ERA	3	43845
4	ERA	4	48849
...	NA	...	...
237	Monotonic	57	34091
238	Monotonic	58	32393
239	Monotonic	59	32975
240	Monotonic	60	38212

```
'data.frame':   240 obs. of  3 variables:
 $ Algoritmo: Factor w/ 4 levels "ERA","CFS","ULE",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ Ejecucion: int  1 2 3 4 5 6 7 8 9 10 ...
 $ Puntaje  : int  45033 46623 43845 48849 45471 47132 46175 44015 46189 48499 ...
    Algoritmo    Ejecucion        Puntaje
 ERA       :60   Min.   : 1.00   Min.   :32283
 CFS       :60   1st Qu.:15.75   1st Qu.:40071
 ULE       :60   Median :30.50   Median :42858
 Monotonic:60   Mean   :30.50   Mean   :42080
                3rd Qu.:45.25   3rd Qu.:45172
                Max.   :60.00   Max.   :49899
```

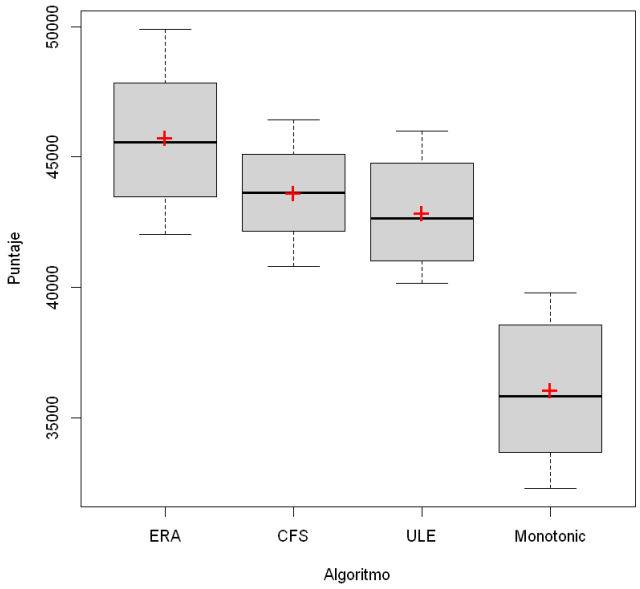
A data.frame: 4 × 9

Algoritmo	n	mean	sd	min	Q1	median	Q3	max
<fct>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
ERA	60	45755.20	2343.695	42040	43468.75	45559.0	47748.25	49899
CFS	60	43627.42	1664.518	40793	42217.25	43622.0	45064.75	46409
ULE	60	42868.75	1929.409	40163	41034.50	42645.5	44726.50	45989
Monotonic	60	36068.55	2503.939	32283	33692.00	35808.5	38542.25	39796

A data.frame: 4 × 6

Algoritmo	n	Mean	Conf.level	Percentile.lower	Percentile.upper
<fct>	<int>	<dbl>	<dbl>	<dbl>	<dbl>
ERA	60	45800	0.95	45200	46300
CFS	60	43600	0.95	43200	44000
ULE	60	42900	0.95	42400	43400
Monotonic	60	36100	0.95	35400	36700

```
Warning message:
"Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
ℹ Please use `linewidth` instead."
```




```
Call:
lm(formula = Puntaje ~ Algoritmo, data = Data)

Residuals:
   Min     1Q Median     3Q    Max
 -3786  -1948   -190   1923   4144

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)        45755.2      275.8 165.899  < 2e-16 ***
AlgoritmoCFS       -2127.8      390.0  -5.455 1.23e-07 ***
AlgoritmoULE       -2886.4      390.0  -7.400 2.37e-12 ***
AlgoritmoMonotonic -9686.6      390.0 -24.835  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2136 on 236 degrees of freedom
Multiple R-squared:  0.7458,    Adjusted R-squared:  0.7425
F-statistic: 230.8 on 3 and 236 DF,  p-value: < 2.2e-16
```

A anova: 2 × 4

	Sum Sq	Df	F value	Pr(>F)
	<dbl>	<dbl>	<dbl>	<dbl>
Algoritmo	3159675063	3	230.7698	6.959249e-70
Residuals	1077095280	236	NA	NA

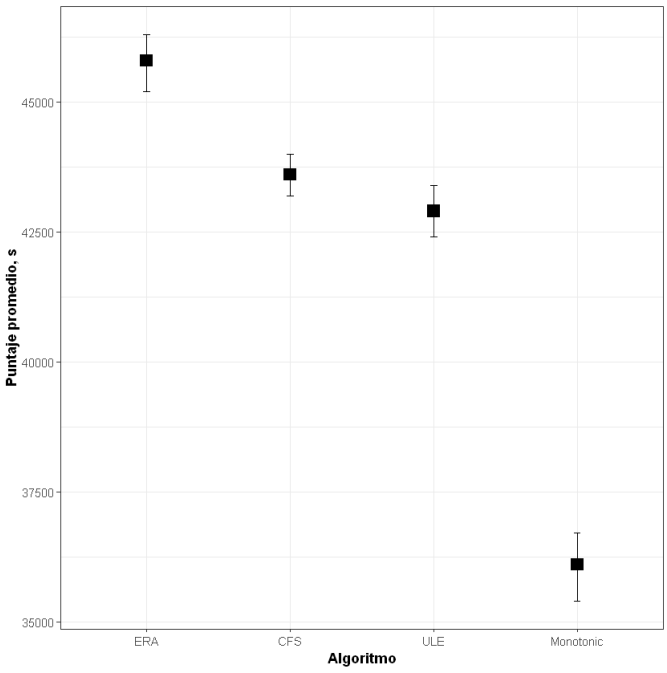
```
 contrast        estimate  SE  df t.ratio p.value
 ERA - CFS           2128 390 236   5.455  <.0001
 ERA - ULE           2886 390 236   7.400  <.0001
 ERA - Monotonic     9687 390 236  24.835  <.0001
 CFS - ULE            759 390 236   1.945  0.2122
 CFS - Monotonic     7559 390 236  19.380  <.0001
 ULE - Monotonic     6800 390 236  17.435  <.0001

P value adjustment: tukey method for comparing a family of 4 estimates
```

```
Loading required package: mvtnorm

Loading required package: survival

Loading required package: TH.data

Loading required package: MASS


Attaching package: 'TH.data'


The following object is masked from 'package:MASS':

    geyser


Note: adjust = "tukey" was changed to "sidak"
because "tukey" is only appropriate for one set of pairwise comparisons
```

A summary_emm: 4 × 7

	Algoritmo	lsmean	SE	df	lower.CL	upper.CL	.group
	<fct>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<chr>
4	Monotonic	36068.55	275.8007	236	35376.27	36760.83	a
3	ULE	42868.75	275.8007	236	42176.47	43561.03	b
2	CFS	43627.42	275.8007	236	42935.14	44319.69	b
1	ERA	45755.20	275.8007	236	45062.92	46447.48	c

```
Warning message in y + params$y:
"longer object length is not a multiple of shorter object length"
```



In [ ]: